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OPTICAL EMISSION FROM COOLING FLOWS IN DISTANT X-RAY CLUSTERS OF GALAXIES

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Although the *Einstein* satellite detected "cooling flows" in the X-ray emission from clusters of galaxies (cf. Sarazin, 1988) 10 years ago, the understanding of these flows remains incomplete. The x-ray emitting gas in the centers of these clusters is so dense that its cooling time is shorter than a Hubble time. Thus gas may cool and flow into the center of the cluster. This cooling gas is thermally unstable (e.g. Mathews and Bregman 1978) and should quickly become inhomogeneous. Optical filamentation (1-100 kpc scales) often appears near the centers of nearby clusters containing cooling flows, usually within the central galaxies accreting the gas (e.g. Ford and Butcher 1979; Hu *et. al.* 1983, 1985). Indeed, only clusters with well-developed cooling flows seem to possess highly luminous, emission-line nebulae (Heckman, *et. al.* 1989). We present here some results of our preliminary observational and theoretical studies of this class of emission-line objects.

We have observed a complete, X-ray selected sample of 25 distant ($0.07 > z > 0.35$) clusters of galaxies extracted from the Einstein Extended Medium Sensitivity Survey (Gioia, *et. al.* 1989.) These clusters have $F_x(0.3 - 3.5 \text{ keV}) \geq 8 \times 10^{-13} \text{ erg/s/cm}^2$, declination $\geq -20^\circ$. We have discovered luminous ($\geq 10^{41} \text{ erg/s}$) extended $H\alpha$ emission in 10 of these clusters. (e.g. Figure 1.) Thus *at least* 40% of the clusters in our sample contain cool gas. (If we crudely compare our sample to that of Arnaud (1988), in which $\sim 40\%$ of his 104 X-ray clusters have cooling flows, our result implies that cooling flows may actually be a more common phenomenon in the past than in the present.

The connection between the cooling flow and the $H\alpha$ emission is a mystery. The straightforward calculation of 1 (photoionization) to 3 (shocks) recombinations per H atom in the cooling flow gives mass infall rates 3 - 100 times greater than \dot{M} derived from X-ray observations (Heckman, *et. al.*, 1989). We have made some preliminary theoretical calculations in an attempt to resolve this problem.

REFERENCES

- Arnaud, K. 1988 in *Cooling Flows in Clusters and Galaxies*, ed. A. Fabian, (Kluwer: Boston), p. 31.
Ford, H. C. and H. Butcher 1979, *Ap. J. Suppl.*, **41**, 147.
Gioia, I. *et. al.* 1989, *Ap. J. Suppl.*, in press.
Heckman, T. *et. al.* 1989, *Ap. J.*, **338**, 48.
Hu, E., Cowie, L. and Wang, Z. 1985, *Ap. J. Suppl.*, **59**, 447.
Hu, E. 1988 in *Cooling Flows in Clusters and Galaxies*, p. 121.
Mathews W.G., and J.N. Bregman 1978, *Ap. J.*, **224**, 308.
Sarazin, C. 1988, *X-ray Emissions from Clusters of Galaxies*, (Cambridge University Press: New York).

MS 0839 + 2938

$z = 0.194$

A) At right, R-band full-field

B) Below left, R-band, close-up

C) Below right, H α , close-up

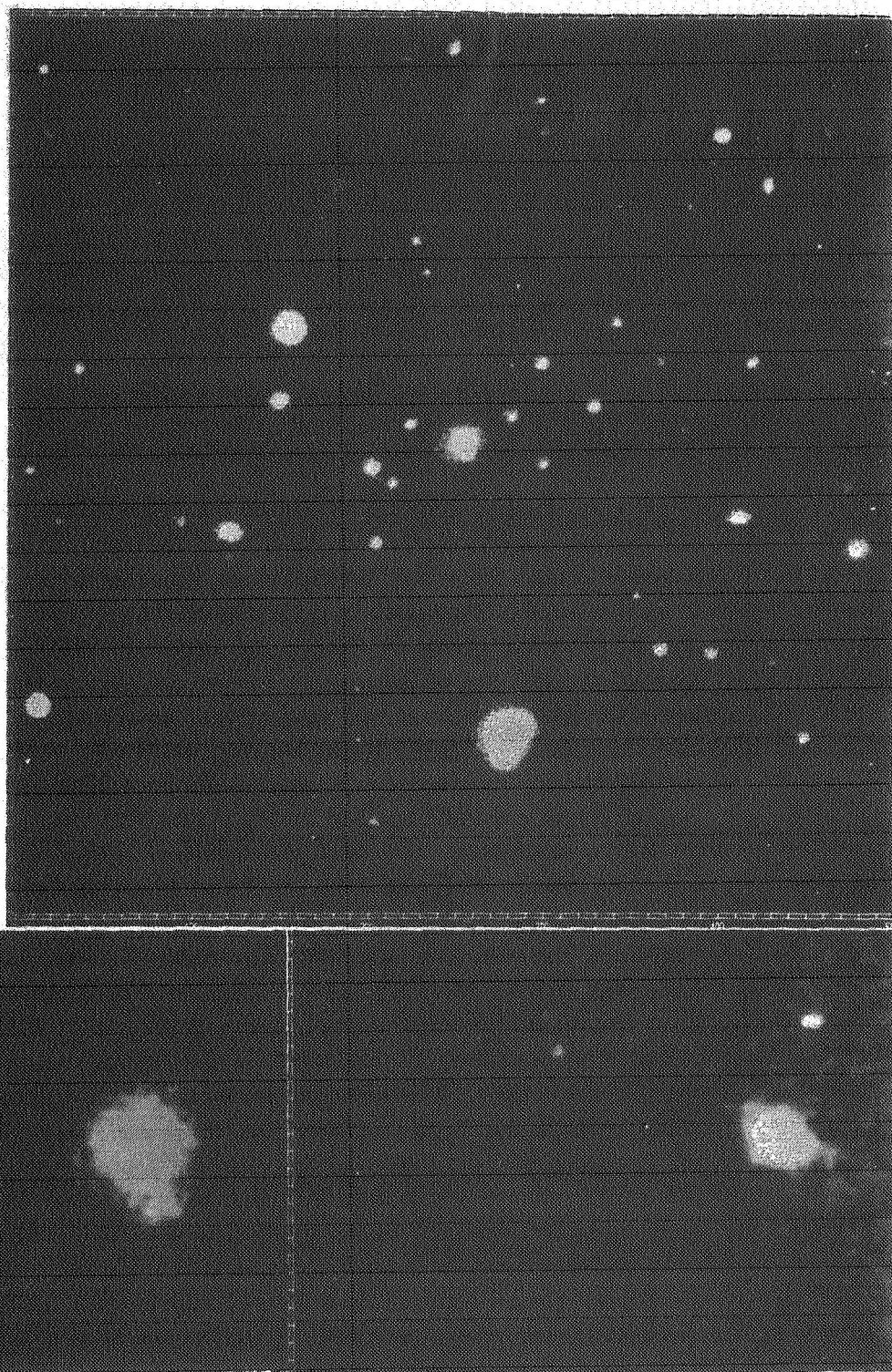


Figure 1: (A) A 3 arcmin x 3 arcmin R band CCD image of the X-ray selected cluster of galaxies MS 0839+2938 ($z = 0.194$). All images obtained with the KPNO 2.1m + Tektronix CCD (Seeing ~ 1.4 arcsecs.)

(B) The central 33 x 20 arcsecs of image (A) showing the red continuum of the central dominant (cD) galaxy.

(C) A pure H α image of the same field as (B) showing the very extended, luminous H α emission associated with the central galaxy and typical of our H α detections of "cooling flows." The bright spot on the upper right is a cosmic ray hit on the chip.